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Implementation of Automatic Load Sharing in Power Transformers Using Arduino Uno

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Abstract: *The rising demand for electricity and the proliferation of high-power appliances have underscored the need for efficient load management in power systems. This paper introduces a prototype model for automatic load sharing among transformers using Arduino UNO. The system dynamically distributes loads between multiple transformers to prevent overloading, ensuring a stable power supply and extending transformer lifespan. By balancing the load efficiently, the proposed solution enhances reliability and reduces the risk of transformer failures. Additionally, the system is cost-effective, scalable, and well-suited for small to medium-scale power distribution networks. Its implementation can significantly improve energy efficiency and reduce operational costs in power distribution systems. The use of Arduino UNO makes the design accessible and adaptable for various real-world applications, offering a practical approach to modern load management challenges.*

Keywords: electricity

I. INTRODUCTION

In traditional power distribution systems, transformers frequently encounter overload conditions, especially during sudden spikes in power demand[4]. Such overloading not only compromises the efficiency of power transmission but also causes severe thermal stress, leading to insulation degradation and, ultimately, transformer failure. These failures not only disrupt the power supply but also incur significant maintenance and replacement costs. Typically, transformer load management relies on manual monitoring and control methods, which are not only labor-intensive and time-consuming but also highly prone to human error. As power demands continue to rise due to the proliferation of high-energy-consuming devices, the limitations of manual load handling become increasingly apparent.

To address this issue, automation in transformer load sharing is becoming a necessity. This paper presents a practical and cost-effective solution in the form of an automatic load sharing system implemented using an Arduino UNO microcontroller. The proposed system is designed to monitor the load on a transformer in real time and compare it with a predefined threshold. When the load on the primary transformer exceeds this threshold, the system automatically triggers a switching mechanism to redistribute the excess load to a secondary transformer. This ensures that no single transformer is subjected to stress beyond its capacity, thereby preventing overheating, improving efficiency, and extending the lifespan of the equipment[5].

The use of Arduino UNO in this system offers a low-cost yet reliable platform for implementing intelligent control logic[3]. It also enables real-time decision-making without the need for continuous human intervention. The prototype model is particularly suitable for small to medium-scale power distribution applications and can be further enhanced by integrating sensors, relays, and wireless communication modules for remote monitoring and control. Overall, the system promotes a smarter, more efficient approach to managing transformer loads in today's increasingly power-dependent world[6].

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II. COMPONENTS REQUIRED

(i) **Arduino UNO :**Arduino UNO is an open-source microcontroller board based on the ATmega328P microcontroller chip. It is one of the most popular boards in the Arduino ecosystem, widely used for prototyping and developing electronics projects due to its simplicity, affordability, and versatility.

Key Features:

Microcontroller: ATmega328P (8-bit AVR architecture) with 32KB flash memory, 2KB SRAM, and 1KB EEPROM[4].

Clock Speed: 16 MHz, providing sufficient processing power for real-time control applications.

Digital I/O Pins: 14 (6 of which can be used as PWM outputs for analog-like control)[5].

Analog Input Pins: 6 (10-bit resolution for reading sensors and analog signals).

Power Supply: Operates at 5V, can be powered via USB, a DC jack (7-12V), or Vin pin.

Communication Interfaces:

UART (Serial) – For serial communication with a computer or other devices[4].

SPI & I2C – For interfacing with sensors, displays, and other peripherals.

Easy Programming: Uses the Arduino IDE, which simplifies coding with a user-friendly environment and a vast library of pre-written functions.

Open-Source: Hardware and software designs are freely available, encouraging modifications and community-driven improvements.

(ii) **Current sensors (ACS712) :**The ACS712 is a Hall Effect-based linear current sensor that can measure both AC and DC currents[6]. It provides an analog output voltage proportional to the sensed current, making it ideal for microcontroller-based projects like transformer load monitoring.

(iii) **Relays:** Relays are electromechanical switches used to control high-power electrical loads with a low-power signal (from Arduino). In an automatic transformer load-sharing system, relays help switch loads between transformers to prevent overloading[5].

(iv) **LCD Display :**An LCD (Liquid Crystal Display) is used in the automatic transformer load-sharing system to provide real-time monitoring and status updates. It helps operators visualize key parameters like load current, transformer status, and system alerts.

(v) **Two step-down transformers (220V AC to 12V AC) :**In an automatic transformer load-sharing system, two step-down transformers (220V AC to 12V AC) are used to demonstrate parallel operation with dynamic load balancing.Convert high-voltage (220V AC) to low-voltage (12V AC) for safe testing and prototyping.Simulate a real-world power distribution system where multiple transformers share loads.Prevent overloading by distributing current between them when one is near capacity[13].

(vi) **Bridge rectifier :**The bridge rectifier converts the 12V AC output from the transformers into DC voltage for powering the Arduino, relays, and sensors.

(vii) **Filter capacitor :**The filter capacitor smooths the pulsating DC output from the bridge rectifier, providing a stable DC voltage for the Arduino and other components.

(viii) **Resistors, wires, breadboard :**These components form the basic infrastructure of the circuit, enabling connections, voltage division, and signal conditioning.

(ix) **Simulated loads (bulbs or resistive elements) :**Simulated loads (such as incandescent bulbs, power resistors, or heating elements) are used to test and validate the load-sharing system under controlled conditions[9].

The overall block diagram of load sharing are shown in figure 1.

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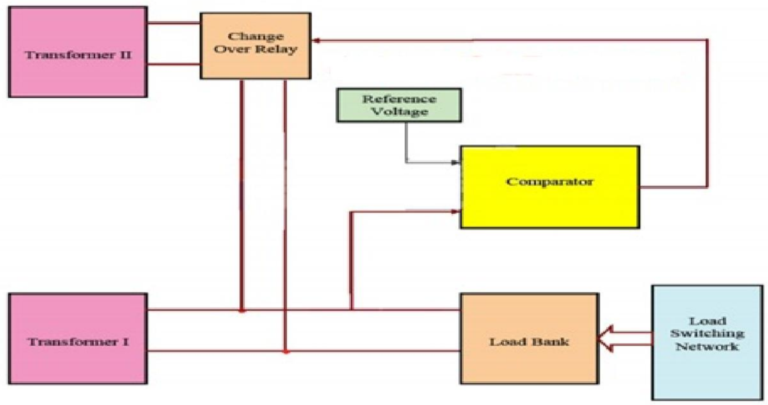

Figure 1: Basic Concept of Load Sharing between Transformers

III. WORKING PRINCIPLE

The proposed system is designed to demonstrate an automatic load-sharing mechanism between two transformers, using Arduino UNO as the control unit are shown in figure 2. The setup comprises two identical step-down transformers, each rated to convert 220V AC mains voltage to 12V AC. These transformers act as the primary sources of input power for the system[16]. The AC voltage output from each transformer is fed into a full-wave bridge rectifier circuit, which converts the alternating current (AC) into direct current (DC)[8]. To ensure the DC output is stable and smooth, the rectified signal is filtered using electrolytic capacitors. The filtered DC voltage is then used to power the electrical loads connected to the system.

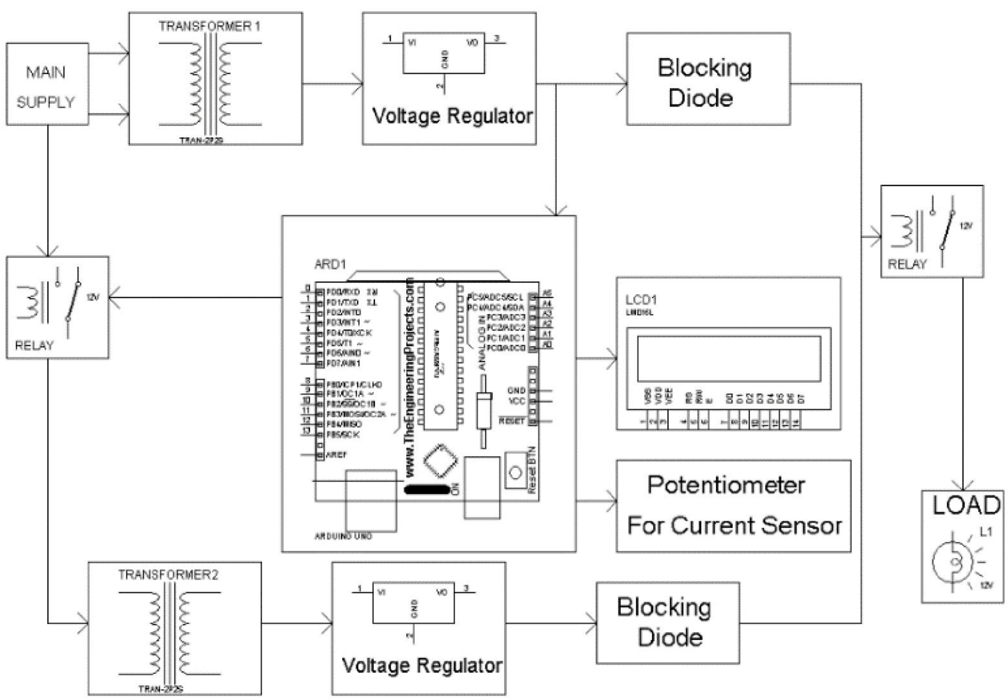

Figure 2: Circuit Block Diagram

To monitor the current flowing through each transformer, ACS712 current sensors are integrated into the circuit[2]. These sensors provide real-time feedback on the amount of current being drawn by the loads. The Arduino UNO reads the sensor data continuously and compares the measured current against a predefined threshold value, which represents

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the safe operating limit for the transformers[7]. If the current drawn from the first transformer exceeds this threshold, the Arduino UNO activates a relay switch to connect the second transformer in parallel, thereby distributing the load between the two units[1]. This automatic switching ensures that neither transformer is overloaded, thus enhancing the safety, efficiency, and longevity of the entire power distribution system.

The relay modules used in the design are capable of handling the required voltage and current levels, ensuring reliable operation during the switching process. The system is fully automated, removing the need for manual intervention in load monitoring and management[11]. This setup is especially suitable for small to medium-scale applications where transformer overload is a common issue due to fluctuating load demands.

Below are the visual representations of the system architecture and its operational logic shows in figure 3.

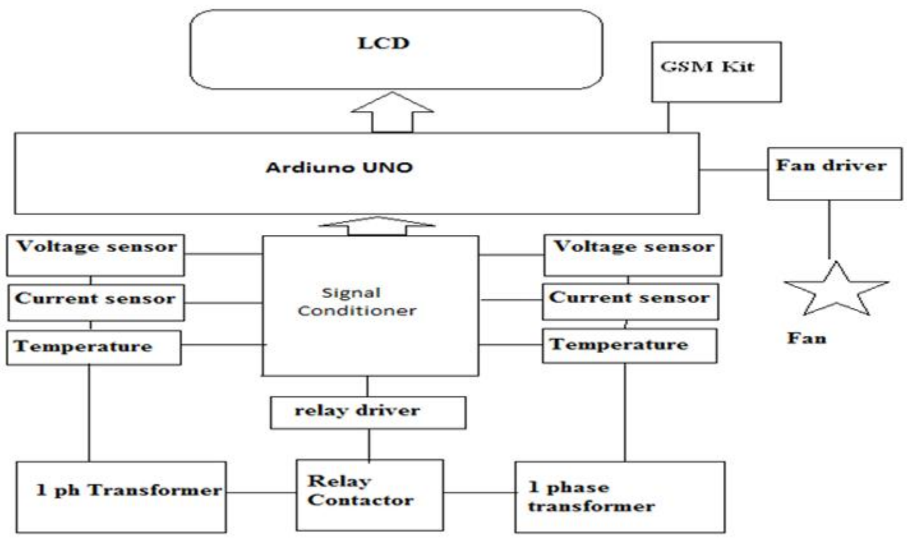

Figure 3: Flowchart of Load Monitoring and Sharing Process

This system not only demonstrates effective load balancing between transformers but also serves as a foundation for more advanced power distribution systems integrated with wireless control and remote monitoring.

IV. SOFTWARE IMPLEMENTATION

The software for the Arduino UNO is developed using C/C++ within the Arduino IDE. It is programmed to read analog input values from the ACS712 current sensors, which are then converted into corresponding current values[10]. The logic includes continuously monitoring these current readings and comparing them against predefined threshold values. When the current on any transformer exceeds its limit, conditional statements trigger the appropriate relay to activate, thereby enabling load sharing between transformers. This simple yet effective control algorithm ensures real-time response and helps prevent overloading, contributing to the overall reliability and efficiency of the power distribution system[11].

V. ADVANTAGES AND APPLICATIONS

Prevention of Overloading:

Automatically shares load between transformers, protecting them from overload conditions that can lead to damage or failure.

Increased Transformer Lifespan:

Reduces thermal and mechanical stress on individual transformers, extending their operational life.

Cost-Effective:

Utilizes affordable components like Arduino UNO and ACS712 sensors, making the system economical and easy to implement[13].

Real-Time Monitoring and Control:
Continuously monitors current and responds instantly to overload conditions, ensuring a reliable power supply.
Automation Reduces Human Error:
Eliminates the need for manual load monitoring and switching, which is prone to delays and errors.
Scalable and Modular:
Can be easily scaled to work with more transformers or integrated with IoT platforms for remote monitoring.
Low Maintenance:
Requires minimal upkeep once installed, with simple components and easy-to-update code.

Applications:
Residential Power Distribution:
Can be used in housing societies or gated communities to manage electricity distribution efficiently.
Commercial Buildings:
Useful in shopping malls, office complexes, and hospitals where continuous and balanced power supply is crucial[14].
Educational Institutions:
Ensures uninterrupted power for labs, classrooms, and administrative areas.
Small Industries:
Ideal for factories and workshops that use multiple transformers to manage varying load conditions.
Temporary Power Systems:
Suitable for event venues, construction sites, or remote locations where dynamic load handling is required.
Smart Grid Systems:
Can be integrated as a part of smart distribution networks for intelligent energy management.

VI. CONCLUSION

This paper presents a practical approach to automatic load sharing between transformers using Arduino UNO. The developed prototype effectively showcases how intelligent control systems can enhance transformer efficiency, prevent overloading, and improve overall system reliability. By continuously monitoring current loads and activating relays when thresholds are exceeded, the system ensures balanced power distribution[15]. The low-cost and scalable nature of the design makes it ideal for small to medium-scale applications. Future improvements may include wireless communication, IoT integration, and cloud-based data analytics, enabling remote monitoring, predictive maintenance, and smarter decision-making for enhanced performance in advanced power distribution networks. The real time monitoring control system shows in figure 4.

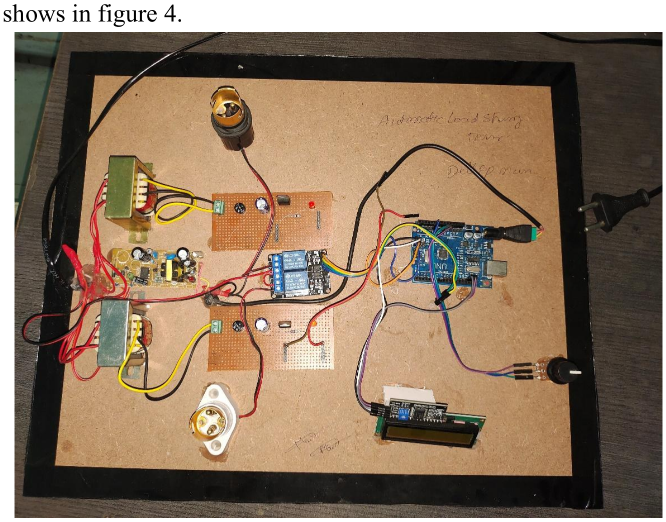

Figure 4: Real-Time Monitoring and Control Setup

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VI. FUTURE SCOPE

The system can be enhanced with IoT capabilities to allow remote monitoring and control of transformer load sharing using mobile or web applications.Integration of wireless communication protocols such as Wi-Fi, GSM, or LoRa for data transmission to central monitoring units[11].The system can be scaled to monitor and manage multiple transformers in large grid systems.Implementation of data logging features for recording load patterns over time and using analytics to predict future load demands[14]. Integration with smart grid infrastructure for automatic decision-making based on real-time data from various nodes in the power distribution system.Automatic detection of faults in transformers or the load-sharing mechanism and real-time alerts to maintenance personnel.

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